CHAPTER 2 Review

REFLECTING ON CHAPTER 2

- Ideal projectiles move in a parabolic trajectory in a vertical plane under the influence of gravity alone.
- The path of a projectile is determined by the initial velocity.
- The range of a projectile is its horizontal displacement.
- For a given magnitude of velocity, the maximum range of an ideal projectile occurs when the projectile is launched at an angle of 45°.
- Projectile trajectories are computed by separately analyzing horizontal and vertical components of velocity during a common time interval.
- Objects in uniform circular motion experience a centripetal (centre-seeking) acceleration: $a_c = v^2/r$.
- A centripetal (centre-seeking) force is required to keep an object in uniform circular motion: $F_c = mv^2/r$.
- Centripetal force can be supplied by any type of force, such as tension, gravitational forces, friction, and electrostatic force, or by a combination of forces.
- The force of gravity has no effect on circular motion in a horizontal plane, but does affect circular motion in a vertical plane.
- Objects moving around banked curves experience a centripetal force due to the horizontal component of the normal force exerted by the surfaces on which they travel.

Knowledge/Understanding

1. Differentiate between the terms "one-dimensional motion" and "two-dimensional motion." Provide examples of each.
2. Explain what physicists mean by the "two-dimensional nature of motion in a plane," when common sense suggests that an object can be travelling in only one direction at any particular instant in time.
3. Describe and explain two specific examples that illustrate how the vertical and horizontal components of projectile motion are independent of each other.
4. When analyzing ideal projectiles, what type of motion is the horizontal component? What type of motion is the vertical component?
5. Standing on the school roof, a physics student swings a rubber stopper tied to a string in a circle in a vertical plane. He releases the string so that the stopper flies outward in a horizontal direction.
   - **(a)** Draw a sketch of this situation. Draw and label the velocity and acceleration vectors at the instant at which he releases the string in order to produce the horizontal motion.
   - **(b)** Explain at what point the horizontal component of the stopper's motion becomes uniform.
6. Explain why an object with uniform circular motion is accelerating.
7. Draw a free-body diagram of a ball on the end of a string that is in uniform circular motion in a horizontal plane. Explain why the weight of the ball *does not* affect the value of the tension of the string that is providing the centripetal force required to maintain the motion.
8. Draw a free-body diagram of a car rounding a banked curve. Explain why the weight of the car *does* affect the value of the centripetal force required to keep the car in a circular path.
9. A rubber stopper tied to a string is being swung in a vertical loop.
   - **(a)** Draw free-body diagrams of the stopper at its highest and lowest points.
   - **(b)** Write equations to show the relationships among the centripetal force, the tension in

the string, and the weight of the stopper for each location.

10. Outline the conditions under which an object will travel in uniform circular motion and explain why a centripetal force is considered to be the *net* force required to maintain this motion.

Inquiry

11. Design and conduct a simple experiment to test the independence of the horizontal and vertical components of projectiles. Analyze your data to determine the percent deviation between your theoretical predictions and your actual results. Identify factors that could explain any deviations.
12. Design and construct a model of a vertical loop-the-loop section of a roller coaster. Refine your model, and your skill at operating it, until the vehicle will consistently round the loop without falling. Determine the minimum speed at which the vehicle must travel in order to complete the vertical loop without falling. Given the radius of your loop, calculate the theoretical value of the speed at which your vehicle would need to be travelling. Explain any deviation between the theoretical prediction and your actual results.

Communication

13. A stone is thrown off a cliff that has a vertical height of 45 m above the ocean. The initial horizontal velocity component is 15 m/s. The initial vertical velocity component is 10 m/s upward. Draw a scale diagram of the stone's trajectory by locating its position at one-second time intervals. At each of these points, draw a velocity vector to show the horizontal velocity component, the vertical velocity component, and the resultant velocity in the frame of reference of a person standing on the cliff. Assume that the stone is an ideal projectile and use 10 m/s^2 for the value of g to simplify calculations.
14. Draw a diagram to represent an object moving with uniform circular motion by constructing a rectangular x–y-coordinate system and drawing a circle with radius of 5 cm centred on the origin. Label the point where the circle crosses the positive y-axis, A; the positive x-axis, B; the negative y-axis, C; and the negative x-axis, D.
    - **(a)** At each of the four labelled points, draw a 2 cm vector to represent the object's instantaneous velocity.
    - **(b)** Construct a series of scale vector diagrams to determine the average acceleration between A and B, B and C, C and D, and D and A. Assume the direction of motion to be clockwise.
    - **(c)** Designate on the diagram at which points the average accelerations would occur and draw in the respective acceleration vectors.
    - **(d)** Write a general statement about the direction of the acceleration of an object in circular motion.
15. The mass of an object does not affect the angle at which a curve must be banked. The law of inertia, however, states that the motion of any object is affected by its inertia, which depends on its mass. How can objects rounding banked curves obey the law of inertia if the amount of banking required for a curve of a given radius of curvature and speed is independent of mass?
16. You are facing north, twirling a tethered ball in a horizontal circle above your head. At what point in the circle must you release the string in order to hit a target directly to the east? Sketch the situation, indicating the correct velocity vector.
17. A transport truck is rounding a curve in the highway. The curve is banked at an angle of 10° to the horizontal.
    - **(a)** Draw a free-body diagram to show all of the forces acting on the truck.
    - **(b)** Write an equation in terms of the weight of a truck, that will express the value of the centripetal force needed to keep the truck turning in a circle.

Making Connections

18. A pitched baseball is subject to the forces of gravity, air resistance, and lift. The lift force is produced by the ball's spin. Do research to find out

(a) how a spinning baseball creates lift

(b) how a pitcher can create trajectories for different types of pitches, such as fastballs, curve balls, knuckle balls, and sliders

(c) why these pitches are often effective in tricking the batter

19. Discuss similarities between a banked curve in a road and the tilt or banking of an airplane as it makes a turn. Draw free-body diagrams for each situation. What is the direction of the lift force on the airplane before and during the turn? Explain how tilting the airplane creates a centripetal force. What must the pilot do to make a sharper turn?

Problems for Understanding

20. You throw a rock off a 68 m cliff, giving it a horizontal velocity of 8.0 m/s.

(a) How far from the base of the cliff will it land?

(b) How long will the rock be in the air?

21. A physics student is demonstrating how the horizontal and vertical components of projectile motion are independent of each other. At the same instant as she rolls a wooden ball along the floor, her lab partner rolls an identical wooden ball from the edge of a platform directly above the first ball. Both balls have an initial horizontal velocity of 6.0 m/s. The platform is 3.0 m above the ground.

(a) When will the second ball strike the ground?

(b) Where, relative to the first ball, will the second ball hit the ground?

(c) At what distance from the base of the platform will the second ball land?

(d) With what velocity will the second ball land?

22. **(a)** A 350 g baseball is thrown horizontally at 22 m/s[forward] from a roof that is 18 m high. How far does it travel before hitting the ground?

(b) If the baseball is thrown with the same velocity but at an angle of 25° above the horizontal, how far does it travel? (Neglect air friction.)

23. A rescue plane flying horizontally at 175 km/h[N], at an altitude of 150 m, drops a 25 kg emergency package to a group of explorers. Where will the package land relative to the point above which it was released? (Neglect friction.)

24. You throw a ball with a velocity of 18 m/s at 24° above the horizontal from the top of your garage, 5.8 m above the ground. Calculate the

(a) time of flight

(b) horizontal range

(c) maximum height

(d) velocity when the ball is 2.0 m above the roof

(e) angle at which the ball hits the ground

25. Using a slingshot, you fire a stone horizontally from a tower that is 27 m tall. It lands 122 m from the base of the tower. What was its initial velocity?

26. At a ballpark, a batter hits a baseball at an angle of 37° to the horizontal with an initial velocity of 58 m/s. If the outfield fence is 3.15 m high and 323 m away, will the hit be a home run?

27. An archer shoots a 4.0 g arrow into the air, giving it a velocity of 40.0 m/s at an elevation angle of 65°. Find

(a) its time of flight

(b) its maximum height

(c) its range

(d) its horizontal and vertical distance from the starting point at 2.0 s after it leaves the bow

(e) the horizontal and vertical components of its velocity at 6.0 s after it leaves the bow

(f) its direction at 6.0 s after leaving the bow

Plot the trajectory on a displacement-versus-time graph.

28. A hang-glider, diving at an angle of 57.0° with the vertical, drops a water balloon at an altitude of 680.0 m. The water balloon hits the ground 5.20 s after being released.
   (a) What was the velocity of the hang-glider?
   (b) How far did the water balloon travel during its flight?
   (c) What were the horizontal and vertical components of its velocity just before striking the ground?
   (d) At what angle does it hit the ground?

29. A ball moving in a circular path with a constant speed of 3.0 m/s changes direction by 40.0° in 1.75 s.
   (a) What is its change in velocity?
   (b) What is the acceleration during this time?

30. You rotate a 450 g ball on the end of a string in a horizontal circle of radius 2.5 m. The ball completes eight rotations in 2.0 s. What is the centripetal force of the string on the ball?

31. A beam of electrons is caused to move in a circular path of radius 3.00 m at a velocity of 2.00×10^7 m/s. The electron mass is 9.11×10^{-31} kg.
   (a) What is the centripetal acceleration of one of the electrons?
   (b) What is the centripetal force on one electron?

32. A car travelling on a curved road will skid if the road does not supply enough friction. Calculate the centripetal force required to keep a 1500 kg car travelling at 65 km/h on a flat curve of radius 1.0×10^2 m. What must be the coefficient of friction between the car's wheels and the ground?

33. Consider an icy curved road, banked 6.2° to the horizontal, with a radius of curvature of 75.0 m. At what speed must a 1200 kg car travel to stay on the road?

34. You want to design a curve, with a radius of curvature of 350 m, so that a car can turn at a velocity of 15 m/s on it without depending on friction. At what angle must the road be banked?

35. **(a)** A motorcycle stunt rider wants to do a loop-the-loop within a vertical circular track. If the radius of the circular track is 10.0 m, what minimum speed must the motorcyclist maintain to stay on the track?
   (b) Suppose the radius of the track was doubled. By what factor will the motorcyclist need to increase her speed to loop-the-loop on the new track?

36. An amusement park ride consists of a large cylinder that rotates around a vertical axis. People stand on a ledge inside. When the rotational speed is high enough, the ledge drops away and people "stick" to the wall. If the period of rotation is 2.5 s and the radius is 2.5 m, what is the minimum coefficient of friction required to keep the riders from sliding down?

37. Use your understanding of the physics of circular motion to explain why we are not thrown off Earth like heavy particles in a centrifuge or mud off a tire, even though Earth is spinning at an incredible rate of speed. To make some relevant calculations, assume that you are standing in the central square of Quito, a city in Ecuador that is located on Earth's equator.
   (a) Calculate your average speed around the centre of Earth.
   (b) Determine the centripetal force needed to move you in a circle with Earth's radius at the speed that you calculated in part (a).
   (c) In what direction does the centripetal force act? What actual force is providing the amount of centripetal force that is required to keep you in uniform circular motion on Earth's surface?
   (d) What is your weight?
   (e) What is the normal force exerted on you by Earth's surface?
   (f) Use the calculations just made and other concepts about circular motion that you have been studying to explain why you are not thrown off Earth as it spins around its axis.